CLINICAL COMMENTARY

CARDIOVASCULAR PREVENTION IN A HIGH RISK SPORT, ICE HOCKEY: APPLICATIONS IN WIDER SPORTS PHYSICAL THERAPY PRACTICE

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ABSTRACT

Although acute myocardial infarction and sudden cardiac death are relatively rare occurrences in athletics, cardiovascular accidents do occur. This manuscript presents information on the cardiovascular risks in athletics. In addition, information is provided on screening for cardiovascular risk – including history taking, chart review, physical examination – and the appropriate guidelines on the treatment of athletes found to be at risk. For the purpose of this article, the sport of ice hockey is used to illustrate the subject matter and highlight the behaviors in sport that carry cardiovascular risk. Physical therapists have ethical and legal responsibility to undertake the necessary screening procedures to recognize and respond to any signs of cardiovascular risk in their clients.

BACKGROUND

The debate regarding the cardiovascular (CV) risks and benefits of vigorous exercise and physical competition has appeared in the literature since ancient times.[1] The benefits of exercise in decreasing all-cause morbidity and mortality in adolescents and older adults hypothesized centuries ago are now well known and well documented.[2-6] The questions for the physical therapist (PT) are: 'What are the CV risks in athletes?,' 'Can those risks be mitigated?,' and 'Should those risks be mitigated?' As with all clinical research, the need exists for more prospective, large, randomized control trials to solidify the answers to these questions. The current state of the literature and the consensus of leading researchers, clinicians, and organizations across the world is sufficient to provide strong answers and to make sound recommendations to physical therapists regarding their practices with athletes. For the purposes of this article, the sport of ice hockey is used to illustrate the subject matter and highlight some of the behaviors in sport that carry CV risk.

EPIDEMIOLOGY OF CARDIOVASCULAR RISK IN ATHLETES

A competitive athlete has been defined as "one who participates in an organized team or individual sport that requires competition against others as a central component, places a high premium on excellence and achievement, and requires some form of systematic training."[7] Given this definition, the primary negative CV events precipitated by exertion reported in the literature are acute myocardial infarction (AMI) and sudden cardiac death (SCD).[8] Thompson and his colleagues[9] reported in 1982 that SCD was seven times more likely during jogging than at rest with one death annually for every 15,240 healthy joggers. Similarly, in 1984 Siscovick et al[10] documented one cardiac arrest each year for every 18,000 healthy men and that the risk was greatest for the habitually least active subjects. In 1993, Mittleman et al[11] and Willich et al[12] provided supporting evidence of the increased risk of AMI with vigorous exercise and that the risk was greatest for the least active individuals. Finally, Van Camp et al,[13] in 1995, estimated the risk of SCD among young athletes as one in every 133,000 males and 770,000 females annually. They cited the US National Center for Catastrophic Sports Injury Research which reported 160 nontraumatic athlete deaths in high school and college organized sports between July 1983 and June 1993, of which 88% were of cardiac etiology. The estimated incidence of sudden death in this group was 7.47:1,000,000 per year in males and 1.33:1,000,000 in females. In athletes over 35, McGrew[14] summarizes estimates of the frequency of SCD as 1:15,000 to 1:50,000 annually. Of note is

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that these data are likely underestimates of the true prevalence of sports-related AMI and SCD because many of the retrospective studies have relied on institutionally reported rates. Unlike the relative risk these authors have reported, the absolute risk that an acute CV event will occur during vigorous exercise in a healthy population has been estimated to be between 1 in 500,000 and 1 in 2,600,000 hours of exercise.[8,11]

PATHOGENISIS OF EXERTION-RELATED CV EVENTS

The cause of exertion-related cardiovascular complications correlates with the athlete's age, with coronary atherosclerosis being the most frequent finding in individuals over the age of 35 to 40 after SCD.[8] Conversely, inherited structural CV abnormalities are the major cause of SCD during exercise in younger athletes.[1,7,10-17] These silent CV diseases predominantly consist of cardiomyopathies, premature coronary artery disease, and congenital coronary anomalies including anomalous coronary artery anatomy, arrhythmogenic right ventricular cardiomyopathy, myocarditis, conduction system abnormalities, and Marfan Syndrome.[16] In the majority of United States reports, hypertrophic cardiomyopathy is documented as being the primary congenital or inherited CV disease linked to SCD in sporting activities accounting for more than one third of deaths.[16,17] It is not the CV abnormality that causes the event but the combination of the physiological changes occurring during exercise and the abnormality. Although the mechanisms of exercise-related AMI and SCD are beyond the scope of this paper, suggested sequelae of these physiological alterations are decreased coronary perfusion, increased myocardial irritability, and altered myocardial conduction.[8]

CARDIOVASCULAR RESPONSES IN ICE HOCKEY

Game Characteristics of Ice Hockey

Hockey originated in Ireland as a field game using a ball and stick called Hurley. In Canada, when the winter arrived, the game moved to the ice and the ball was replaced by the puck. The word "hockey" is probably derived from the French *hoquet* ("shepherd's crook"), referring to the shape of the stick.[18] Hockey is now Canada's national game and played seriously, at recreational and elite levels, in 20 countries. The game involves five active skaters on each team covering a 200' by 85' ice rink surface. Most elite competitive games are played in climate controlled arenas whereas, recreational games may be indoors or, alternatively, on outdoor rinks in a wide variety of weather conditions. For protection, players in all venues wear substantial gear with full body coverage. Game play is for 3 periods of 20 minutes each. The nature of the game of hockey is to have the players take 1.5-3 minute shifts of high intensity skating on the ice and 2.0-5.0 minutes off the ice throughout the 60 minutes of play. Each period is also separated from the next with a 15 minute break in play. These bouts of intermittent exercise followed by stationary rest periods have been studied specifically in ice hockey by a handful of published researchers to determine the physiological and morphological myocardial adaptations as well as the demands on the CV systems of the athletes.[19-24]

The Elite Hockey Player

Elite ice hockey players present with an increase in left ventricular (LV) cavity size, wall thickness, and mass, as well as a reduction in resting heart rate (HR) and blood pressure (BP). These findings are typical of a combination of sports requiring predominantly sprint work (wall thickness) and endurance work (cavity size).[19,25] Physiologically, using the Fick Equation [$VO_{2\ max}$ = Q x a-$vO_{2\ difference}$], where endurance capacity ($VO_{2\ max}$) is the result of cardiac output (CO = Q) and the ability to extract oxygen (a-$vO_{2\ difference}$) and where CO is the result of left ventricular stroke volume (SV) times HR, in the hockey player it appears that an increase in SV is the method for increasing CO for play. Conversely, in control groups of healthy age matched peers, the increased CO is primarily derived from an increase in HR.[19] In both groups an increase in a-$vO_{2\ difference}$ occurs but the increase is greater in the elite hockey players.[19,21] In addition, ice hockey is often described as an anaerobic sport, a fact supported by Bossone et al[19] in their study of elite college ice hockey players who noted their requirement to tolerate anaerobic debt.

An analysis of the CV demands involved in playing ice hockey, and similar intermittent exercise sports, is performed by measuring the intensity of the CV workload at any given time during play, rest, and into recovery. Exercise at moderate intensities of 50 to 70% of oxygen uptake reserve (VO_{2max} – VO_{2rest}), 60 to 80% heart rate reserve (HRR = HR_{max} – HR_{rest}) or 70 to 85% of age-predicted maximum HR (HR_{max}) have been widely demonstrated to be safe and beneficial.[20,26] The American College of Sports Medicine (ACSM) estimates maximum predicted HR in a healthy population as HR_{max} = 220 – age in years in beats per minute(bpm).[26] The ACSM and Canadian Association of Sports Sciences both advocate target heart rate zones for training that do not exceed 85%

of predicted HR_{max} in healthy populations.[26] Yet, authors report that these hockey players frequently exceed 85% of both measured and predicted HR_{max} during bouts of play on the ice for between 10-30% of on-ice time, with their HRs returning to below 60% HR_{max} during rest.[21-23] Perhaps as interesting, a finding in a study of elite women hockey players by Spiering et al[23] indicated that these players experienced significantly greater CV load during game play than during practice (mean working HR during the game 90 +/- 2%, during practice 76 +/- 3%; mean percent session time >90% HR_{max} during the game 10.5% +/- 4%, during practice 5.6 +/- 3.5%).[25] Further, Paterson's[21] literature search suggested a reduced efficiency of the thermoregulatory system in intermittent exercise, placing added demand on the CV system.

Adult Recreational Hockey

The most widely cited study of adult recreational ice hockey is the 2002 *Hockey Heart Study* conducted as a descriptive, cross-sectional study of male players in Sydney, Nova Scotia (n=113; average age 42.7 +/- 6.9).[24] All subjects were over 35 years of age and were without known CV diseases or abnormalities. Atwal et al[24] assessed participant symptoms, HR, heart rhythm, and electrocardiogram (ECG) changes. In 100% of subjects, HR_{max} during play was greater than target exercise HR, calculated as 55-85% age-predicted HR_{max}(mean 184 +/- 11). The mean duration of these elevated HRs was 30 +/- 13 SD minutes. In addition, for 70.1% of data sets, HR recovery was poor, dropping as little as 4 bpm in the first minute of recovery when a drop of >12 bpm is correlated with lower CV risk.[24,26] Also of concern were the recordings of non-sustained ventricular tachycardia from two monitoring sessions and ST-segment depression indicating myocardial ischaemia in data from 15 sessions. Symptoms reported while playing hockey included one report each of shortness of breath, palpitations, and chest pain or heaviness. No incidents of AMI or SCD were reported. Another finding of these particular recreational hockey players was that, although the authors reported a few risk factors present in adult recreational hockey players, no association existed with ischaemic heart disease and sudden death.[24] In his published commentary of the study and recreational hockey, Mittleman[27] stated that the participants had not received adequate primary prevention. Yet, despite elevated cholesterol levels (52.8%) and strong family histories of CV disease (41%), over 60% of the participants did exercise ≥3 times per week (excluding hockey) and were not considered sedentary. This exercise history appeared to have a substantial protective effect considering the risk of an AMI or SCD triggered by vigorous exertion is approximately 50 times higher among sedentary people.[11]

RATIONAL FOR CLIENT PRE-SCREENING FOR CARDIOVASCULAR RISK

Cardiovascular Risk Levels

Ice hockey is a sport requiring high intensity CV workloads for short bouts of intermittent exercise with maximum HRs exceeding current guidelines of ≤85% of HR_{max} for a large percentage of the time spent on-ice. This intensity translates into an elevated relative risk level of 2-2.5 fold. In absolute terms, though, the risk is extremely low.[10-12] Despite this fact, clinicians must recognize that one CV event or one death is a result that must be avoided if at all possible. The risk in individuals under the age of 35 correlates with undiagnosed cardiovascular abnormalities such as hypertrophic cardiomyopathy or premature atherosclerosis. In individuals over the age of 35 the strongest correlations with risk are the incidence and degree of CV risk factors such as hypertension, smoking, dyslipidemias, sedentary lifestyle, diabetes, central obesity, and elevated body mass index (BMI).[17,26,28] In both age groups, these indicators can be screened for. In the case of the younger athletes and CV pathology, a referral to a medical physician for elite athletes has been recommended.[14,16,17,29-31] Alternatively, although prescreening is recommended for all individuals 35 years of age and older, the initial screening can be performed by all clinicians trained in CV risk and risk prevention.[3-5,8,20,26,28,32]

Physical Therapist's Legal And Ethical Liability

Physical therapists across North America are now primary care practitioners in many jurisdictions giving the public direct access to our services. With this right comes an ethical and legal responsibility to screen for any risks associated with the initiation of, or return to, sport. This responsibility becomes especially true when the possible outcome is as extreme as a CV event or death. Further, the principle of beneficence held by the PT as a primary ethical foundation suggests that the access to athletes and the knowledge base and scope of practice allow the PT to determine their CV risk and take that information to mitigate that risk through education, training and rehabilitation.

CARDIOVASCULAR EVENT PREVENTION

Screening for Cardiovascular Risk

Recognizing and mitigating CV risk by physical therapists takes two forms: (1) the assessment and (2) training regimes, including coaching and athlete education. A screening process should have target outcomes that have a significant impact on morbidity and mortality and should be accurate, practical to apply, and relatively low in cost.[30] A PT history taking and physical assessment of athletes of every level can meet all of these goals *(Figure 1)*.

Physical Therapy Assessment: History Taking and Chart Review

The components of a PT history taking that are key to documenting increased CV risk related to both (i) discovering the non-modifiable and modifiable known CV risk factors *(Table 1)* and (ii) getting an accurate symptom and event history. The modifiable CV risk factors include: hypertension, smoking, dyslipidemias {low high density lipoprotein (HDL) levels or elevated cholesterol, total cholesterol/HDL ratio, triglycerides, and low density lipoprotein (LDL) levels}, sedentary lifestyle, diabetes mellitus (DM), depression, central obesity, and elevated body mass index (BMI).[26,33] Although international guidelines may vary somewhat in target values of some of the risk factors, strong consensus exists on healthy ranges. Of note is that individuals of a lower socioeconomic bracket are

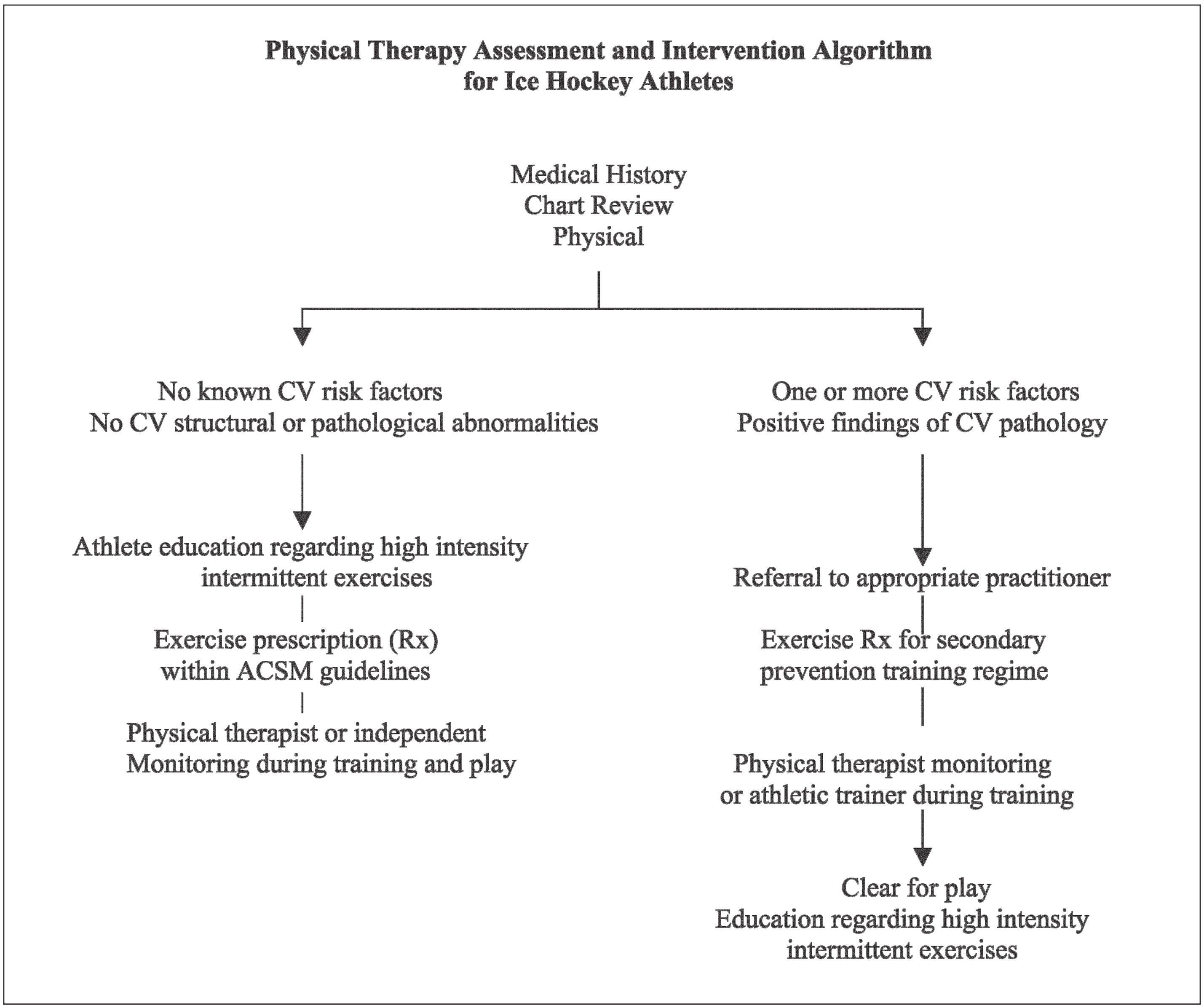

Figure 1: Physical Therapy Assessment and Intervention Algorithm for Ice Hockey Athletes and athletes of similar intermittent exercise sports.

also known to have a greater incidence of atherosclerosis, CV, and cerebrovascular events. If any single modifiable risk factor is borderline or exceeds recommended levels, the PT should communicate the findings to the client's family physician. The PT may also make direct referrals to clinicians whose scope of practice addresses any one or more key risk factor.

heart beat, dizziness, nausea, lightheadedness, and diaphoresis (heavy perspiration). Individuals may not initially report these symptoms but when they reveal that they are not as active as they were five years earlier, the clinician may be able to probe more specifically to determine if the reason is the avoidance of one or more of these symptoms. The clinician should also note if the client has a history of calf discomfort with exertion that resolves with rest possibly suggesting peripheral arterial disease or claudication.

CV Risk Factors for the Development of Atherosclerosis (Target Definitions)

Non-modifiable:
1. advancing age ($VO_{2\,max}$ decreases ~ 10% per decade)
2. male sex
3. ethnicity (Canadian First Nations, South Asian, African American, African Caribbean, Mexican American)[32,34,35]
4. family history (premature deaths, vascular disease in surviving relatives)
5. genetic factors

Modifiable:
1. tobacco smoking (any exposure)
2. physical inactivity (< 30 to 60 minutes moderate exertion most days of the week;[26] < 1.5 kcal/kg body weight/day[32])
3. over-weight (> 25 BMI); obesity (>30 BMI)*
4. increased waist circumference- central obesity (_ >90 cm; _ >100 cm)*
5. excessive alcohol consumption (< 2/day; _<9/week, _ <14/week)
6. hypertension (<140/90 mmHg in the absence of co-morbidities)*
7. dyslipidemia (total cholesterol > 5.0 mmol/L; LDL >2.5 mmol/L; HDL _< 1.3 mmol/L, _ < 1.0 mmol/L) ; total cholesterol HDL ratio < 4.0; triglycerides < 1.7 mmol/L)*
8. diabetes mellitus (fasting blood glucose 6.0 mmol/L; 2-hour post-prandial < 7.8 mmol/L)*
9. depression

* Metabolic Syndrome is a cluster of three or more specific risk factors that increases overall CV risk

Emerging Risk Factors / Markers of Vascular Disease:
1. C-reactive protein (high sensitivity) – inflammatory marker (>1.0 mg/L)
2. lipoprotein(a) – lipid related factor
3. fibrinogen – haemostasis thrombosis marker
4. homocysteine - other
5. erectile dysfunction

The symptoms *(Table 2)* most closely related to atherosclerosis are angina (chest discomfort or heaviness; aching in the chest, neck or jaw; radiation into the shoulder or arm), shortness of breath, palpitations or irregular

Primary Symptoms of Myocardial Ischaemia
1. chest discomfort or heaviness (angina) 2. aching in the neck or jaw, radiation into the shoulder or arm 3. shortness of breath (dyspnea) 4. irregular heart beat (palpitations) 5. dizziness, lightheadedness 6. nausea 7. diaphoresis (heavy perspiration)

Table 2: The symptoms most closely linked to a decreased myocardial oxygen supply due to atherosclerosis.

Although the ordering of tests such as echocardiograms, electrocardiograms, graded exercise tolerance tests (GXT), Holter monitor, or blood work is within the scope of the physician, the PT must make sure that any relevant test results are sourced, recorded, and then taken into account when undertaking an exercise prescription. For athletes under 35 years of age, particular attention is given to determining if there is any known inherited structural CV abnormalities. Similarly, the client's current medications should be recorded. If these tests have been performed, it may be a red flag and the PT should follow up with the family physician to enquire about the client's CV health. Males over 40 and females over 50 years of age should undergo a GXT every two years if healthy or annually if they have known CV disease.[26,28] If the client has not undergone a GXT as recommended, the PT should discuss this with their client and refer them to their physician for follow up.

Physical Therapy Assessment: Physical Examination

In addition to the usual PT musculoskeletal and neuromuscular scans and assessment procedures, any client who is going to be prescribed exercise at moderate or high intensities must have basic vital signs and any symptoms recorded including their HR and rhythm, blood pressure, and ventilatory rate both at rest *and with exercise*. Vital signs should be taken on more than one occasion to verify them. The Borg Rating of Perceived Exertion (RPE) is also highly correlated with exertion and should be used to assess and monitor athletes.[26]

Player Guidelines

Mitigation of Risk

Several components exist for minimizing CV risk when undertaking any sport, but this reduction in risk is especially true of sports, such as ice hockey, involving high intensity bouts of intermittent exercise, including the following:

Training. Training regimes must include aerobic training at moderate to high intensities 3 to 5 times per week to optimize VO_{2max}. In addition, practices must incorporate periods of high intensity exercise of similar duration to those encountered in game play. Athletes should be charged with self-monitoring shifts on and off the ice. Athletes should also spend 2-3 sessions on resistance training for the primary muscles used on the ice.

Pre-game preparation. Athletes should take a dietician's advice on nutritional needs for play but should recognize the risk of any significant intake of solid foods within one hour of a practice or game due to the high oxygen cost of digestion. To decrease cardiac workload from vascular resistance through vasodilation and to promote increased CO, athletes should warm-up by performing continuous aerobic exercise for 8 to 20 minutes prior to play. Pre-game hydration is also important in preparation for myocardial and skeletal muscle cell elevated metabolism during play. Dehydration can cause a significant increase in workload on the heart causing elevated heart rates and body temperature, lowered BP, and up to a 50% loss in performance. To avoid over-heating, players must consider their clothing and gear from the perspective of the temperature of the arena on the day of play.

During the practice or game. Players must avoid an abrupt drop in HR and BP when coming off the ice to avoid situations where myocardial oxygen supply does not meet demand, as well as to ensure they are ready for the next bout on-ice. To do this the player can remain standing and perform intermittent static or dynamic muscle contractions of the large muscle groups of the body. Hydration remains vital. Any signs or symptoms of CV deficit must be noted and reported. Players must also recognize any signs of over-heating and take action to cool themselves down (cold applied to the neck or wrists, removing gloves).

Immediately following the game. Players need to allow 12 to 20 minutes to let their HR and BP to decrease gradually, ensuring again that oxygen supply continues to meet the elevated metabolic rate anticipated for an extended period after exercise. This "cool down" is very difficult given current practices of heading immediately for the locker room to debrief and change. Marching on the spot, walking, or any type of movement during this period can help to pace the drop in CO.

Education

Players and coaches in sports involving high intensity bouts of intermittent exercise should be approached and informed of the CV risks and how to mitigate those risks. Training should be laid out for the athletes and, in the case of recreational athletes, monitored for sufficient frequency, duration, and intensity. Although elite ice hockey is unlikely to change its format of play, recreational hockey groups can revise warm-up and cool-down routines to optimize CV health.

CONCLUSIONS

The benefits of recreational or elite ice hockey participation well outweigh the risks of AMI and SCD during play. As Mittleman[27] describes it, the risk of AMI in an hour of vigorous exertion is doubled compared to rest but their risk of CV events in the other 23 hours of the day is 50% lower than a sedentary individual.

The risks of ice hockey are sufficient to warrant prescreening and targeted interventions to mitigate that risk. Physical therapists have an ethical and legal imperative to undertake the necessary assessment procedures to recognize and respond to any signs or findings of elevated CV risk in their clients. The basic parameters for assessing and mitigating CV risk for ice hockey players should apply equally to other sports with bouts of high intensity intermittent exercise.

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